

**Joint Research Centre**

# **Introduction to the Gamma Spectrum Generator**

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Supporting legislation*



Nucleonica - Gamma Spectrum Generator - Mozilla Firefox

Datei Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe

http://www.nucleonica.net/Application/Spectrum/Spectrum.aspx

Meistbesuchte Seiten Erste Schritte Aktuelle Nachrichten

Nucleonica - Gamma Spectrum Gene...

nucleonica ... web driven nuclear science

Applications Data Knowledge My Preferences Print Help New Browser

Eu152

1.6 h 9.28 h 13.53 y

**Gamma Spectrum Generator**

63 Europium

Actual chart: Karlsruhe

Getting started  
Reference manual

Questions, remarks, suggestions  
can be posted in the forum

Element: Mass:  
Eu 152

Nuclide Mixtures Selector

Quantity: Reference point:  
Bequerel 1000000 Measurement start

Measurement setup Calculation results Options

Measurement time: sec 1000 Start Start in background

Current configuration: Nal, L x D = 3 in x 3 in (default) Save as Delete

Dimensions in mm

Source

Filter

Nal Crystal

76.2 Crystal diameter

250.0 Source to Detector distance

76.2 Crystal length

Show more settings

Fertig

How to get to the GSG page:

1. Select Applications->Gamma Spectrum Generator from the Nucleonica's main menu

OR

2. Go to the Nuclear Science Applications Portal and select Gamma Spectrum Generator from the application list

# Presentation outline

## GSG in basic mode

- Modeling approach
- Introduction to the GSG features
- Experimental validation of the GSG

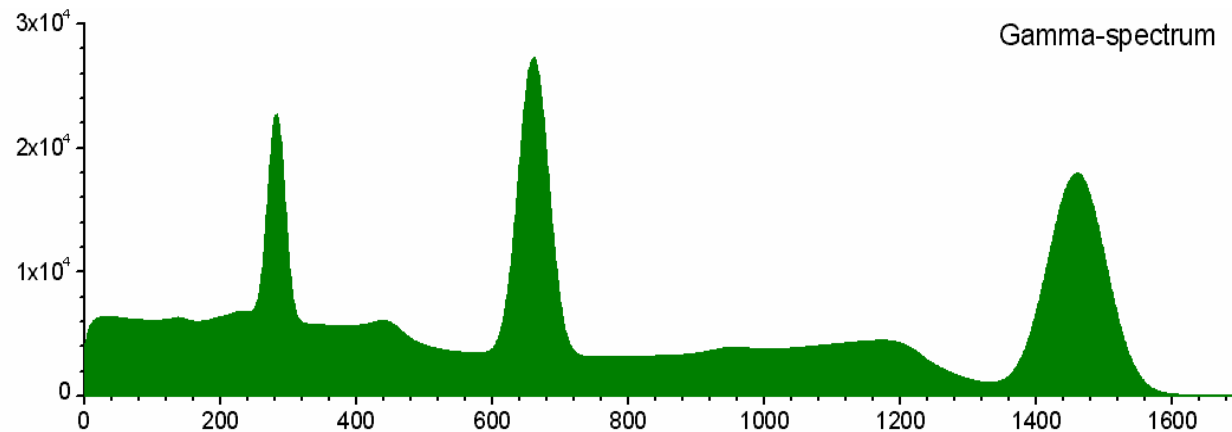
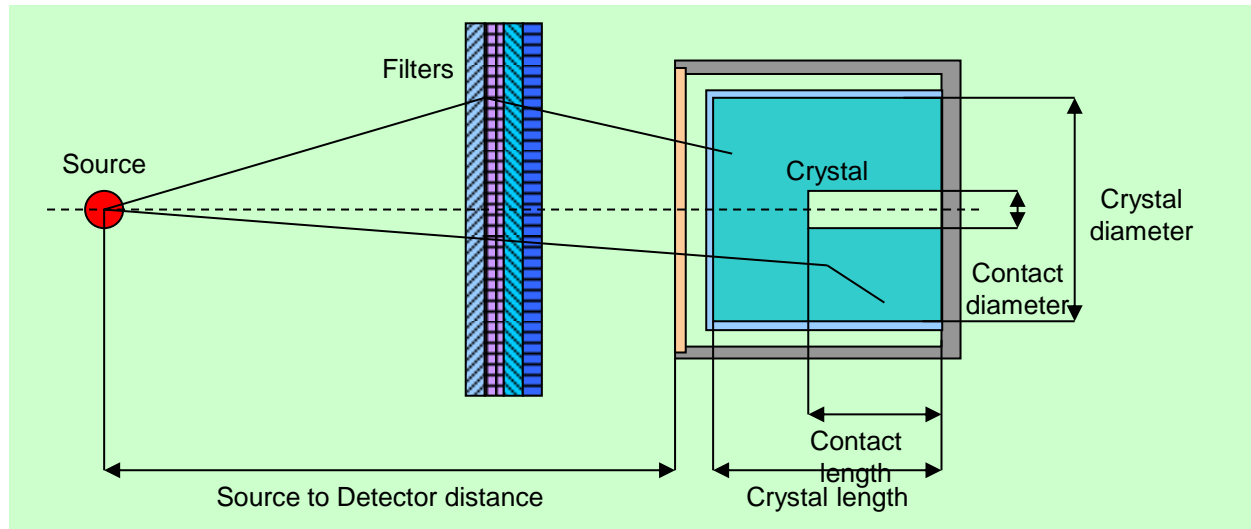
## GSG-PRO

- Additional modeling features

## Exercises

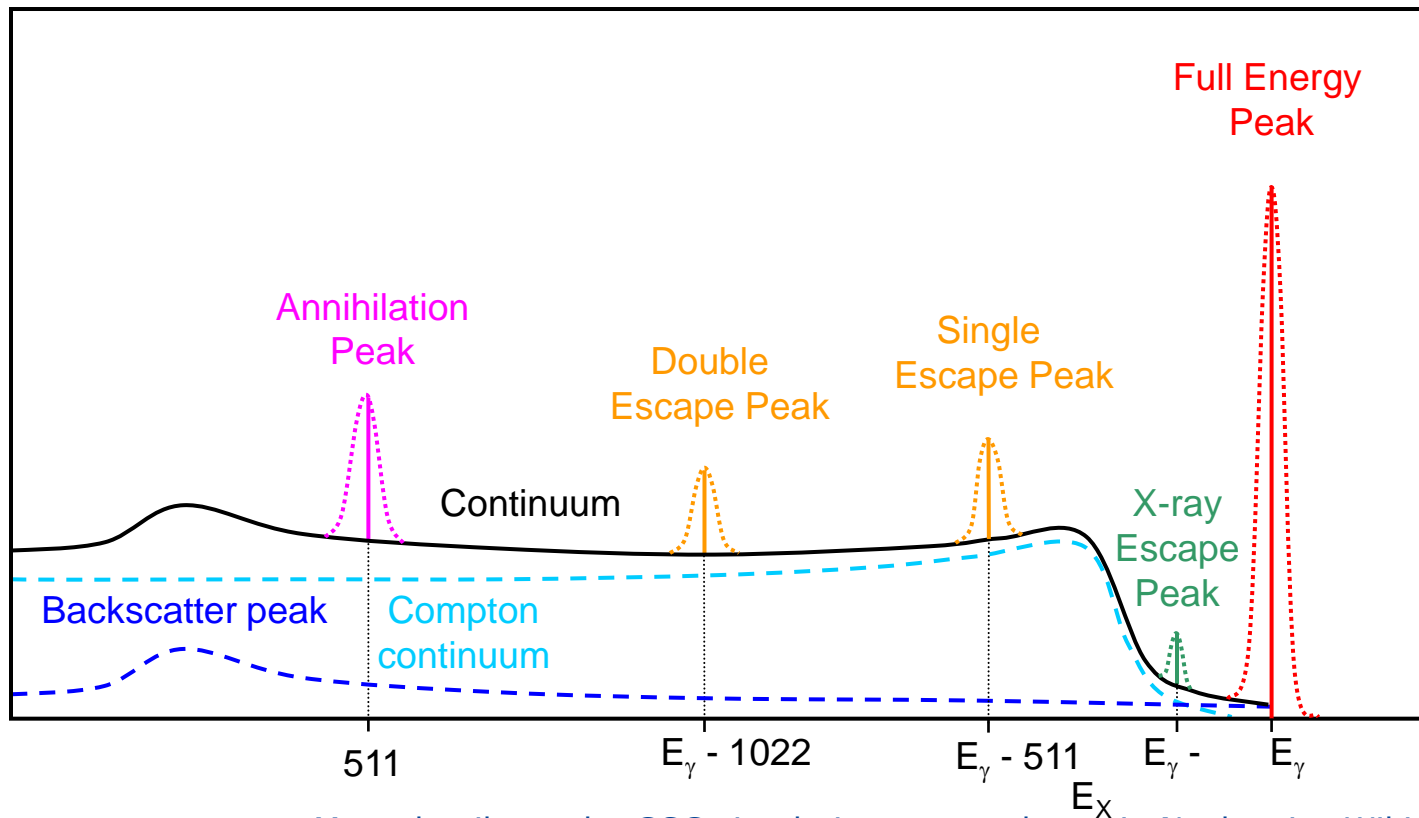
# GSG in basic mode: Modeling approach

Measurement setup model implemented:



## GSG in basic mode: Modeling approach

- For spectrum modeling the GSG uses a comprehensive database of detector responses for gamma-ray energies from 10 keV to 10 MeV, which were obtained using extensive Monte Carlo simulations



- More details on the GSG simulation approach see in Nucleonica Wiki at [http://www.nucleonica.net/wiki/index.php/Help:Gamma\\_Spectrum\\_Generator](http://www.nucleonica.net/wiki/index.php/Help:Gamma_Spectrum_Generator)

# GSG in basic mode: GSG features

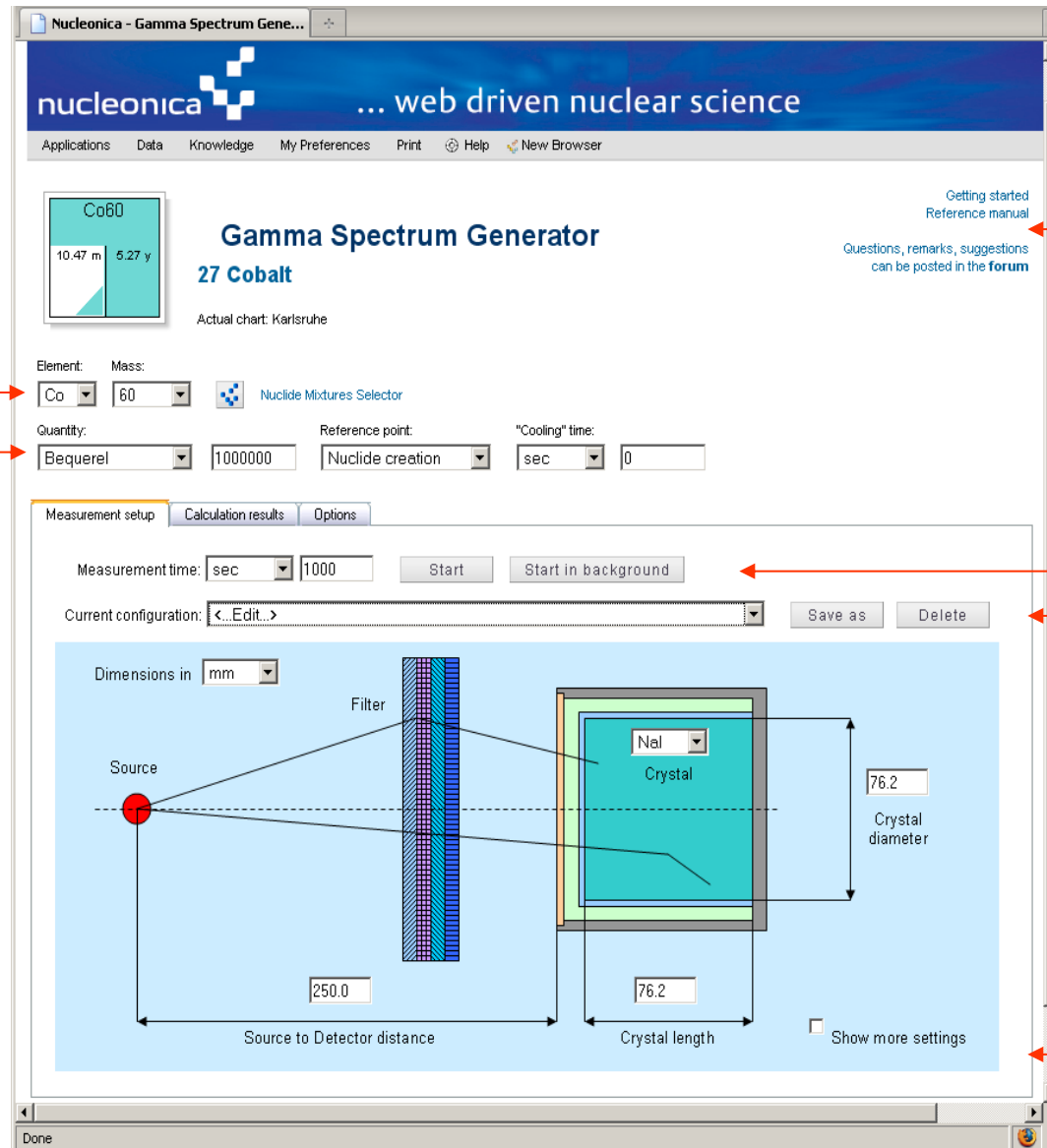
Select an arbitrary individual nuclide or a pre-defined mixture of nuclides as a radiation source

Specify the quantity (activity, mass, number of atoms, dose rate) of a nuclide or a mixture either

- at the spectrum measurement starting point of time, or
- at the moment of nuclide/mixture creation.

In the last case, the controls for specifying duration of a source “cooling” time interval become available.

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Applications Data Knowledge My Preferences Print Help New Browser

Getting started  
Reference manual

Questions, remarks, suggestions  
can be posted in the [forum](#)

**Gamma Spectrum Generator**  
27 Cobalt  
Actual chart: Karlsruhe

Element: Co Mass: 60 Nuclide Mixtures Selector

Quantity: Bequerel Reference point: Nuclide creation "Cooling" time: sec 0

Measurement setup Calculation results Options

Measurement time: sec 1000 Start Start in background

Current configuration: <...Edit...> Save as Delete

Dimensions in mm

Source Filter NaI Crystal

Crystal diameter 76.2

Source to Detector distance 250.0 Crystal length 76.2

Show more settings

Links to the quick start and detailed reference manuals, as well as to the GSG user's forum

Press “Start” button to start a simulation

• Choose a suitable  $\gamma$ -spectrometer from 6 pre-defined configurations, including HPGe and NaI detectors, or

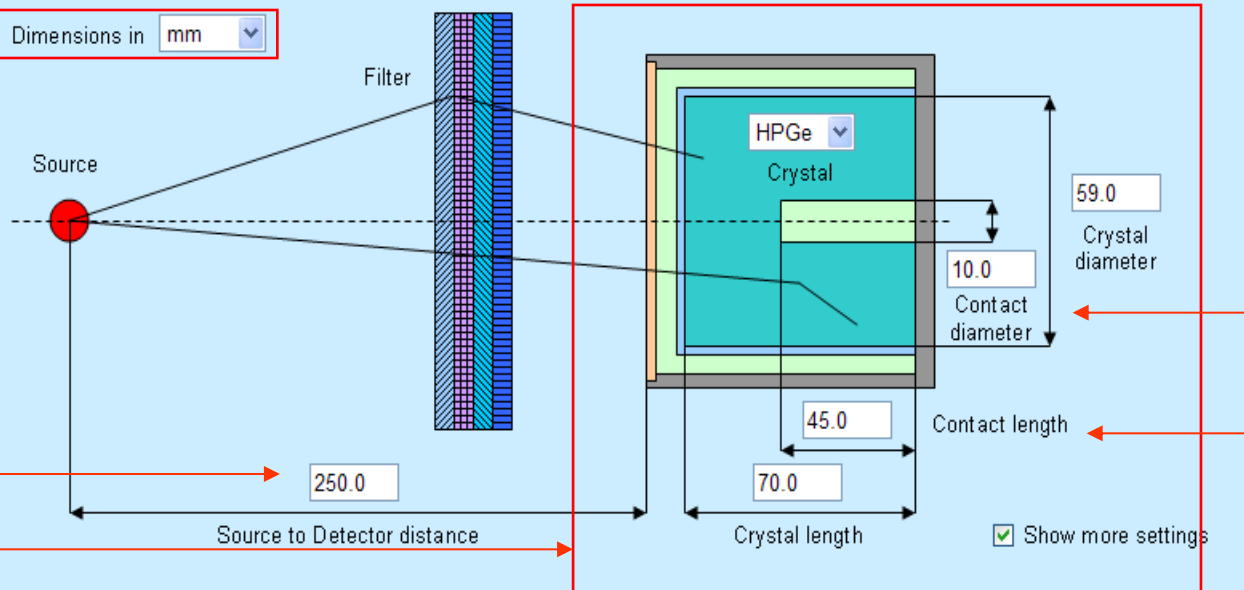
• Select “Edit” to create a new spectrometer.

Tick the checkbox to get access to additional spectrometer settings

# GSG in basic mode: GSG features

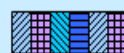
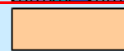
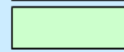

Configuring a new spectrometer:

Dimensions can be entered in "mm", "cm" or "inch" units



The dimensions of a cylindrical contact at the rear side of the crystal (a construction feature of conventional coaxial HPGe detectors) can be specified

The configurable parameters include the source-to-detector distance, as well as dimensions and materials of the detector construction elements.

	Filter:	Aluminum	0.2
	Input window:	Aluminum	0.5
	Crystal packaging:	Vacuum	3.0
	Inactive layer / Reflector:	Germanium	0.5

Number of channels in the spectrum accumulated: 8192

Channel-to-energy conversion factor, keV/channel: 0.3

Energy resolution (FWHM) in keV at 122 keV: 0.8

Energy resolution (FWHM) in keV at 1332 keV: 1.8

No.	Layer material	Thickness
1	Copper	1.0
2	Tin	0.5
3	Lead	0.1
4	Aluminum	0.2

Up to 6 additional absorbing filters made of Al, Cu, Fe, Pb, Sn, or polyethylene can be placed between source and detector

# GSG in basic mode: GSG features


Selecting calculation options:

Nucleonica - Gamma Spectrum Generator - Windows Internet Explorer

http://localhost:1652/WebSite1/Application/Spectrum.aspx#

Live Search

Nucleonica - Gamma Spectrum Generator

 **Gamma Spectrum Generator**  
Natural Uranium

Actual chart: Karlsruhe

Nuclide Mixtures:  
Natural Uranium Nuclide Selector

Total activity:  
Bequerel 2.557e+004

Reference point:  
Measurement start

Measurement setup Calculation results Options

Gamma Spectrum Generator Settings:

- ☒ Display detector efficiency curves
- ☒ Consider decay transformations during cooling and counting time intervals
  - ☒ Include gamma-rays of daughter nuclides
  - 0.01 Decay Engine's accuracy factor
- ☒ Consider effects of backscatter radiation
  - 1.0 Backscatter peak normalisation factor

Efficiency  
Graph can be  
activated in the  
Calculation  
Results output

The backscatter  
peak simulation  
can be switched  
on/off, and its  
contribution to  
the spectrum  
can be adjusted

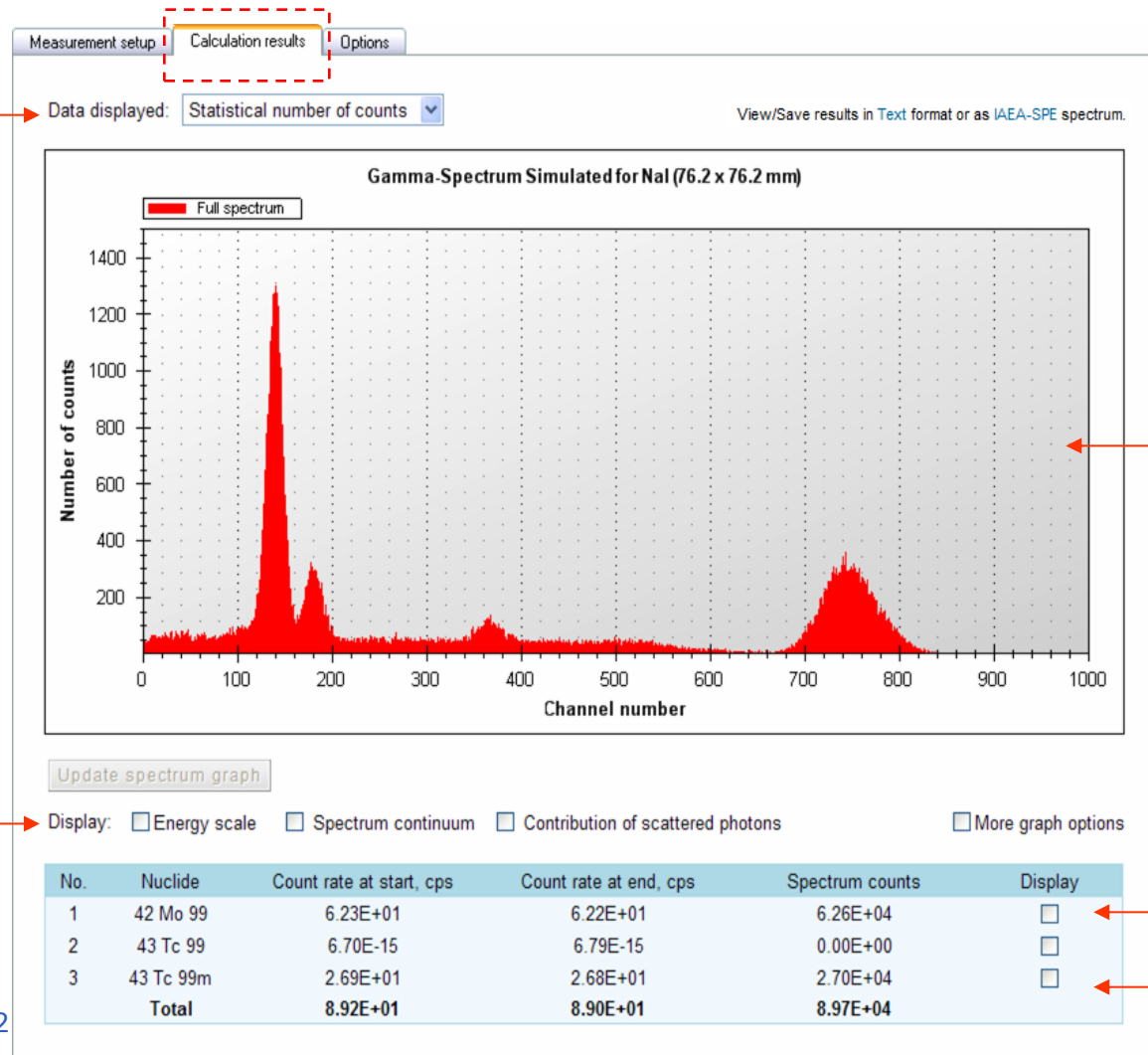
Decay  
calculations can  
be enabled that  
will allow  
contributions  
from decay  
products, being  
accumulated  
during source  
cooling and  
spectrum  
measurement  
time intervals

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# GSG in basic mode: GSG features

Exploring calculation results:



Statistical number of counts  
Count rate at start  
Count rate at end  
Theoretical number of counts  
Statistical number of counts

Spectral information can be saved as a text file as IAEA-SPE spectrum or Excel.

Right click within the graph area enables a context menu, from which one can print or download the spectrum graph

Additional options allow to customize appearance of the graph to meet one's needs and requirements

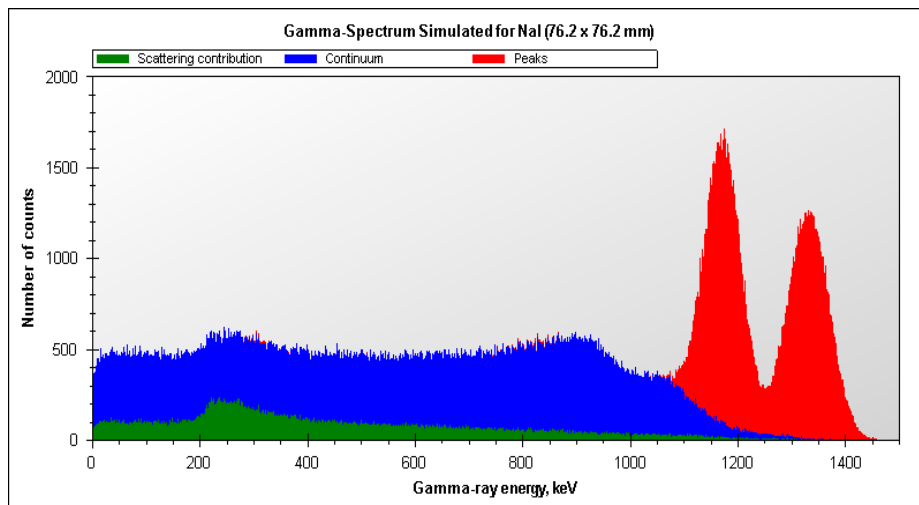
Display nuclide specific contributions to the full spectrum

Switch between channel number and energy scale; show peak, continuum and backscatter peak contributions to the full spectrum

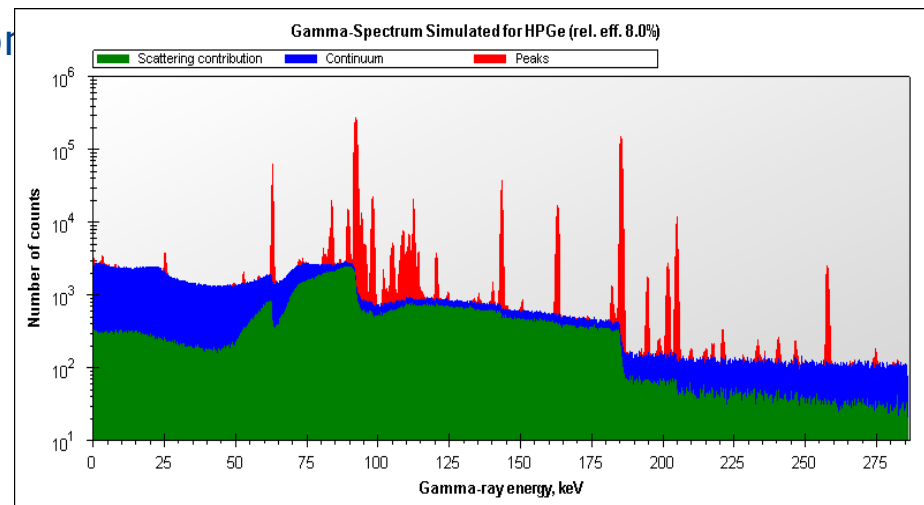
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# GSG in basic mode: GSG features

100 kBq  $^{60}\text{Co}$



1 g Nat U (2 years after separation)

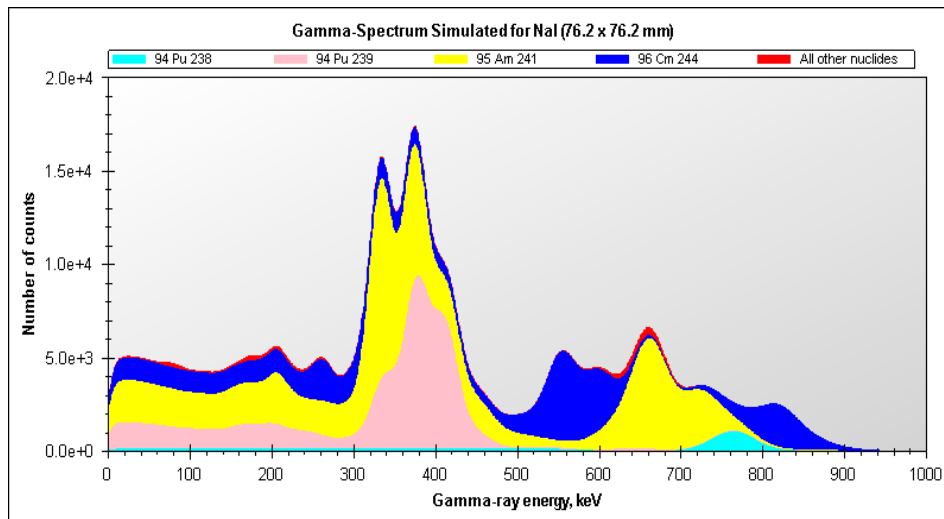


Detector - NaI ( $\varnothing 3'' \times 3''$ )  
Source-to-detector distance - 25 cm  
Measurement time - 1000 s

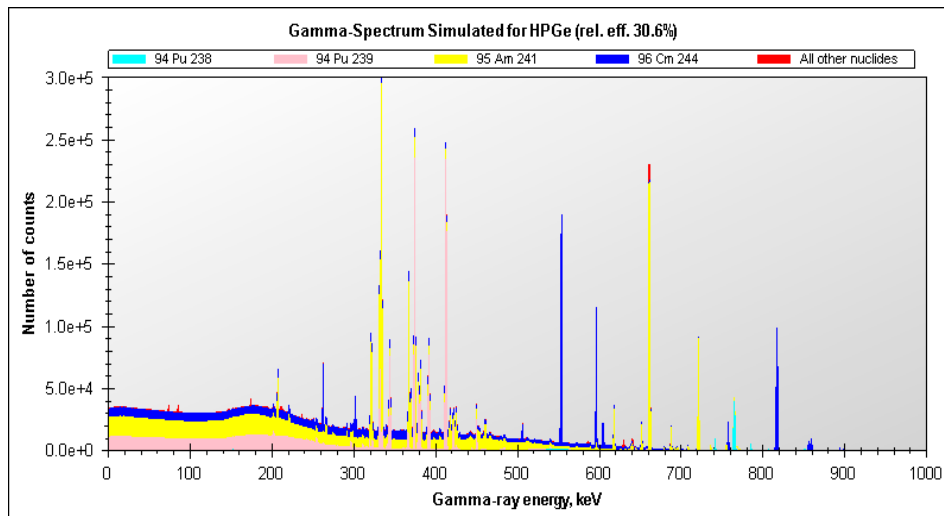
Detector – LEGe (20 mm  $\times$  2800 mm<sup>2</sup>)  
Source-to-detector distance – 25 mm  
Filter – 0.5 mm Sn  
Measurement time -  $10^5$  s

# GSG in basic mode: GSG features

Displaying contributions of different nuclides:



Detector – NaI (Ø3"×3")  
Source-to-detector distance – 25 cm  
Filter – 5 mm Pb  
Measurement time - 1000 s



**Actinides extracted from 1 kg  
6-year-aged PWR spent fuel.  
Activity - 5.25 TBq**

Detector – BEGe (30% rel. eff.)  
Source-to-detector distance – 25 cm  
Filter – 5 mm Pb  
Measurement time - 1000 s

# GSG in basic mode: GSG features

Saving calculation results in Text / Excel formats:

**Calculation Parameters**

	A	B	C	D	E
1	<b>Nucleonica - GAMMA SPECTRUM GENERATOR Version 1.0.0.1</b>				
2	File content: Calculation Results				
3	Created: 4/17/2008 3:21:29 PM (UTC)				
4					
5	<b>SPECTROMETER:</b>				
6	Configuration name: Noname				
7	Crystal type: HPGe				
8	Crystal length: 52.00 mm				
9	Crystal diameter: 72.20 mm				
10	Contact length: 36.00 mm				
11	Contact diameter: 10.00 mm				
12	Inactive layer: 0.90 mm Germanium				
13	Crystal packaging: 5.00 mm Vacuum				
14	Detector input window: 1.50 mm Aluminum				
15	Number of additional filters: 0.00				
16	Filter No. 1: 0.00 mm				
17	Filter No. 2: 0				
18	Filter No. 3: 0				
19	Filter No. 4: 0				
20	Filter No. 5: 0				
21	Filter No. 6: 0				
22	FWHM at 122 keV: 0				
23	FWHM at 1332.5 keV: 0				
24	Number of channels: 8				
25	Channel-to-Energy conversion: 4				
26	Source-to-Detector distance: 17				
27	Spectrum measurement time: 1				
28					
29					
30	<b>SOURCE:</b>				
31	Nuclide: 56 Ba 137m				
32	Quantity: 1				
33	Reference point of time: N				
34	Source cooling interval: 30 min				
35					
36	<b>CALCULATION:</b>				
37	Consider decay transformations: Yes				
38	Include gammas of daughter nuclides: Yes				
39	Decay engine's accuracy factor: 0.01				
40	Consider backscatter radiation: Yes				
41	Backscatter peak normalization factor: 2				
42					

**Nuclide Specific Data**

	A	B	C	D	E	F	G	H	I
1	<b>Nuclide</b>	<b>Ancestor</b>	<b>Activity, Bq</b>		<b>Number of</b>	<b>Count rate, cps</b>		<b>Number of counts</b>	
2			<b>at start</b>	<b>at end</b>	<b>decays</b>	<b>at start</b>	<b>at end</b>	<b>theor.</b>	<b>statist.</b>
3	55 Cs 137	55 Cs 137	1.000E+00	1.000E+00	1.000E+00	5.652E-08	5.652E-08	5.652E-08	0.000E+00
4	56 Ba 137m	55 Cs 137	9.437E-01	9.395E-01	9.416E-01	7.177E-03	7.144E-03	7.160E-03	0.000E+00
5	<b>TOTAL:</b>		<b>0.000E+00</b>	<b>0.000E+00</b>	<b>0.000E+00</b>	<b>7.177E-03</b>	<b>7.144E-03</b>	<b>7.160E-03</b>	<b>0.000E+00</b>
6									

**Gamma and X-ray Data**

Energy, keV	X/G ray	Emission rate, 1/s at start	Emission rate, 1/s at end	Photons emitted	Peak region counts peak area	Peak region counts peak bkg	Detection efficiency total	Detection efficiency FEP	Ancestor's MDA(0), Bq
3.50	G	5.800E-06	5.800E-06	5.800E-06	2.715E-08	4.094E-05	7.530E-03	4.681E-03	1.441E+08
47	X	9.837E-03	9.793E-03	9.815E-03	0.000E+00	2.757E-05	0.000E+00	0.000E+00	NAN
82	X	1.951E-02	1.943E-02	1.947E-02	5.198E-07	3.363E-05	2.775E-05	2.676E-05	9.635E+08
19	X	3.600E-02	3.584E-02	3.592E-02	1.137E-06	3.301E-05	3.285E-05	3.171E-05	1.997E+08
40	X	1.310E-02	1.304E-02	1.307E-02	2.193E-06	3.211E-05	1.727E-04	1.681E-04	5.304E+07
1.66	G	8.500E-01	8.462E-01	8.481E-01	1.960E-03	2.144E-06	6.715E-03	2.311E-03	1.964E+03

Gamma-rays Efficiency : 96 Ba 137m / 55 Cs 137 / Full spectrum.

1.176E-04 4.578E-03

6.804E-04 56.70 %

137\_270mm\_Spectrum.xls

File Tools Data Window Help

Type a question for help

Gamma Spectrum

pel number

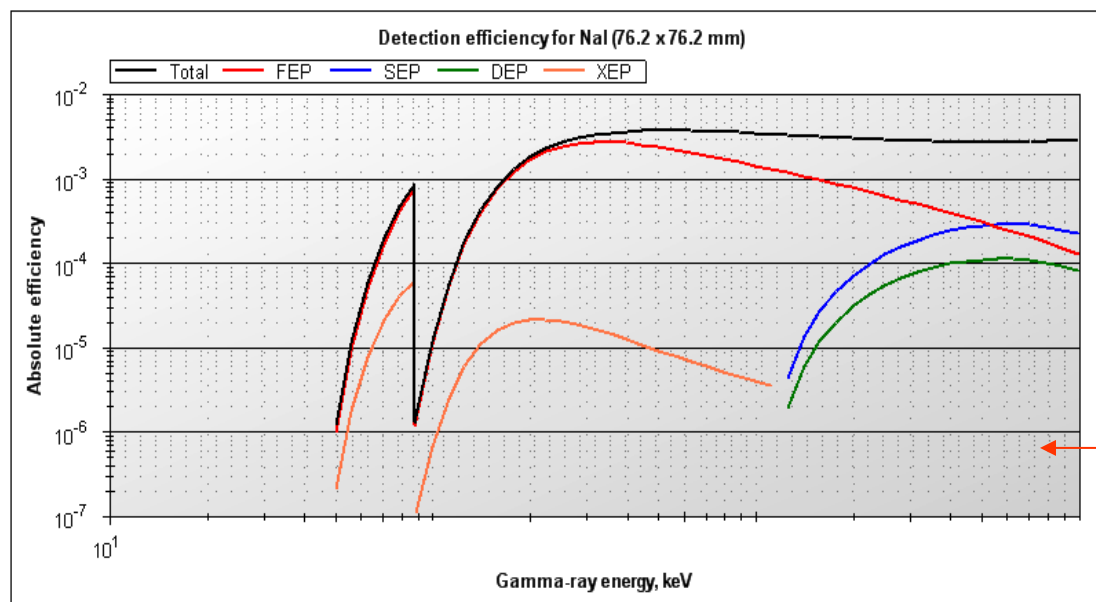
		D	E	F	G	H	I	J	K	
1		Count rate at start, cps			Count rate at end, cps			Theoretical number of counts		
2	Energy, keV	Continuum	Scattered	Total	Continuum	Scattered	Total	Continuum	Scattered	Total
3	0.20	2.637E-06	8.042E-07	2.650E-06	2.625E-06	8.006E-07	2.638E-06	2.631E-06	8.024E-07	2.644E-06
4	0.60	3.185E-06	9.725E-07	3.218E-06	3.171E-06	9.681E-07	3.204E-06	3.178E-06	9.703E-07	3.211E-06
5	1.00	3.335E-06	1.019E-06	3.376E-06	3.320E-06	1.015E-06	3.360E-06	3.327E-06	1.017E-06	3.368E-06
6	1.40	3.381E-06	1.035E-06	3.394E-06	3.366E-06	1.030E-06	3.379E-06	3.373E-06	1.032E-06	3.387E-06
7	1.80	3.400E-06	1.042E-06	3.401E-06	3.385E-06	1.037E-06	3.395E-06	3.392E-06	1.039E-06	3.393E-06
8	2.20	3.411E-06	1.046E-06	3.411E-06	3.396E-06	1.042E-06	3.396E-06	3.404E-06	1.044E-06	3.404E-06
9	2.60	3.421E-06	1.050E-06	3.421E-06	3.405E-06	1.046E-06	3.405E-06	3.413E-06	1.048E-06	3.413E-06

Efficiency 56 Ba 137m 55 Cs 137 Full spectrum

Ready

# GSG in basic mode: GSG features

Plotting detection efficiencies:



Update efficiency graph

Efficiencies displayed: ☒ Full Energy Peak (FEP) ☒ Single Escape Peak (SEP) ☒ Total  
☒ X-ray Escape Peak (XEP) ☒ Double Escape Peak (DEP)

☒ More graph options

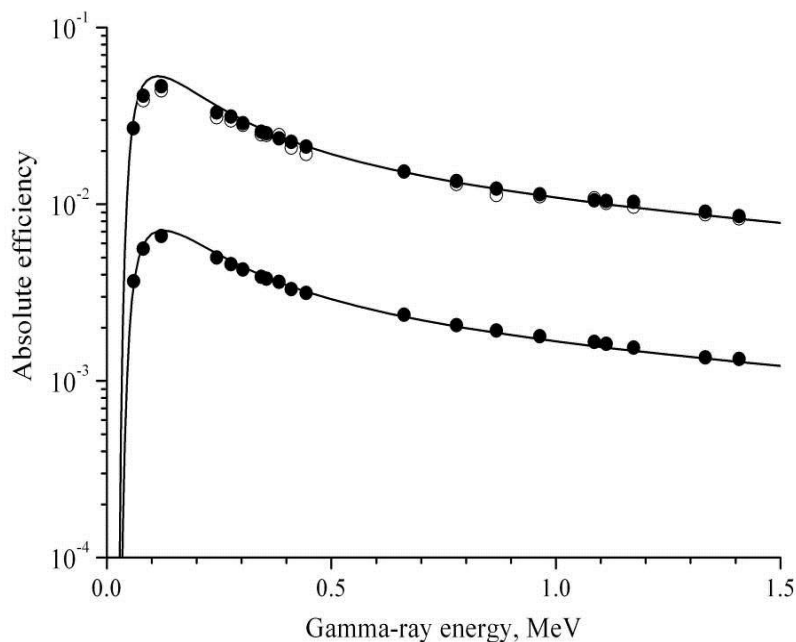
X-axis settings:		Y-axis settings:	
<b>Scale</b> <input checked="" type="checkbox"/> Auto <input checked="" type="checkbox"/> Log Minimum: 10 Maximum: 10000	<b>Tick steps</b> <input checked="" type="checkbox"/> Auto Major step: 1000 Substeps No: 5	<b>Scale</b> <input checked="" type="checkbox"/> Auto <input checked="" type="checkbox"/> Log Minimum: 0 Maximum: 1.00	<b>Tick steps</b> <input checked="" type="checkbox"/> Auto Major step: 0.01 Substeps No: 5
<b>Grid lines</b> <input checked="" type="checkbox"/> Major <input checked="" type="checkbox"/> Minor	<b>Ticks</b> <input checked="" type="checkbox"/> In <input checked="" type="checkbox"/> Out <input checked="" type="checkbox"/> Labels	<b>Grid lines</b> <input checked="" type="checkbox"/> Major <input checked="" type="checkbox"/> Minor	<b>Ticks</b> <input checked="" type="checkbox"/> In <input checked="" type="checkbox"/> Out <input checked="" type="checkbox"/> Labels

Right click within the graph area enables a context menu, from which one can print or download the efficiency graph

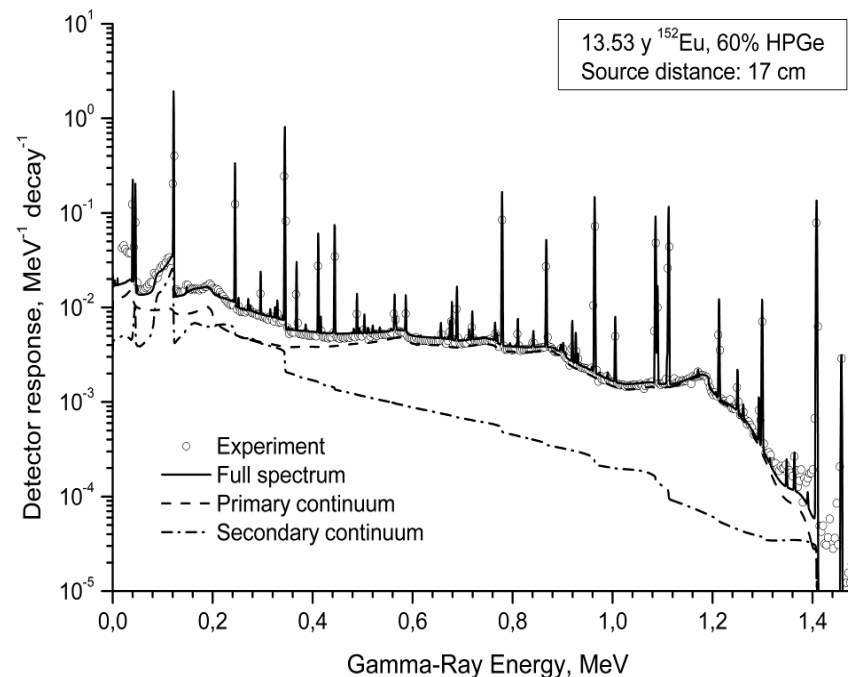
Select efficiency data to be displayed on the graph

Additional options allow to tailor the efficiency graph to one's needs and requirements

## GSG in basic mode: Experimental validation (HPGe)



Full Energy Peak efficiency as a function of the photon energy: circles – experimental values, curve – calculated. Two sets of data refer to the source location at 5 cm and 17 cm distances from the detector end cap.

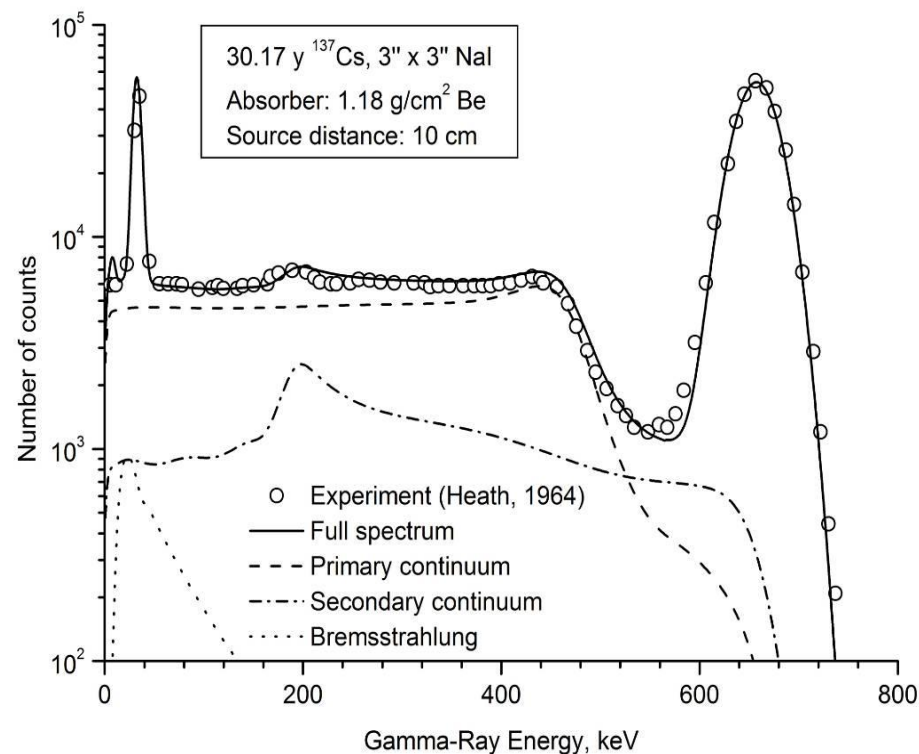
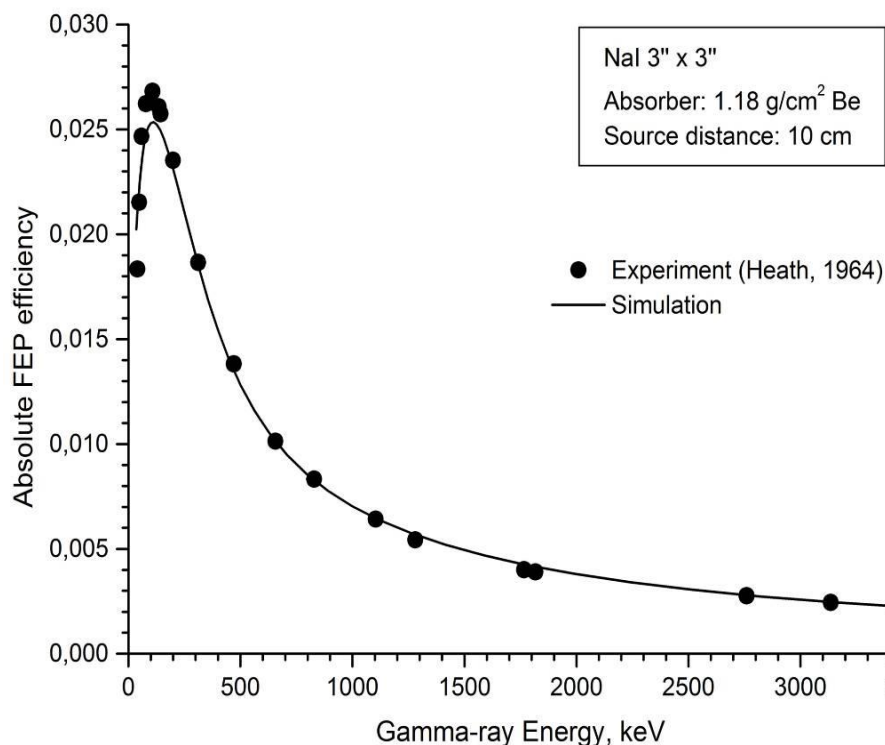


Calculated (curve) and experimental (circles) detector responses for  $^{152}\text{Eu}$  source at 17 cm distance from the detector end cap.



## GSG in basic mode: Experimental validation (NaI)

### Results of the experimental validation with 3" × 3" NaI scintillation detector

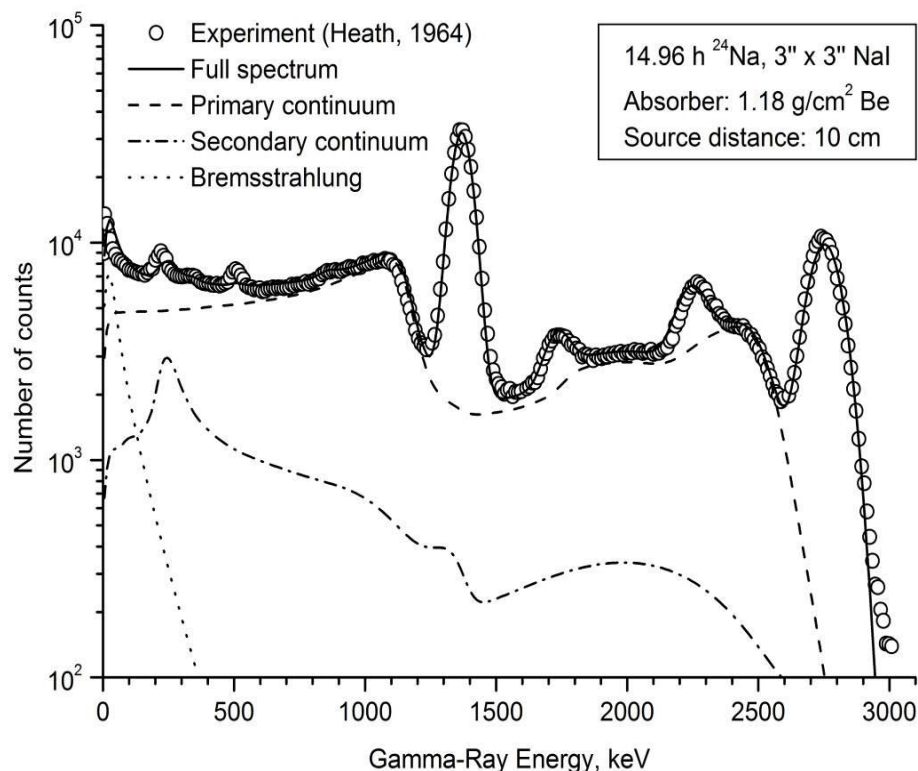


The simulated vs. experimental *FEP* efficiencies for a NaI 3" × 3" detector.

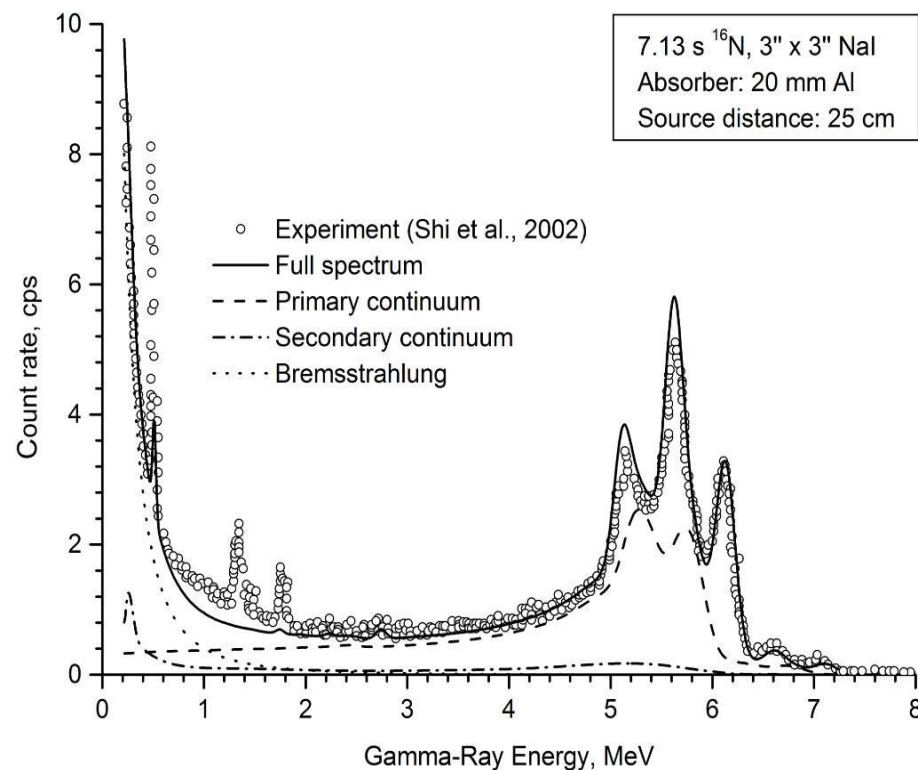
The experimental and simulated spectra for <sup>137</sup>Cs and a NaI 3" × 3" detector .

## GSG in basic mode: Experimental validation (NaI)

Results of the experimental validation with 3" × 3" NaI scintillation detector



The experimental and simulated spectra for  $^{24}\text{Na}$  and a NaI 3" × 3" detector.



The experimental and simulated spectra for  $^{16}\text{N}$  and a NaI 3" × 3" detector.







# GSG-PRO: Additional modeling features

1. Modeling of a contribution from naturally occurring radionuclides (natural gamma radiation background)

## Additional interface features:

Additional measurement setup properties:

	Absorbing filter layers:	Aluminum	1.0	Add	Del	No.	Layer material	Thickness
	Input window:	Aluminum	0.5					
	Crystal packaging:	Foam Plastic	0.0					
	Inactive layer / Reflector:	Aluminium oxide	0.5					

ADC and energy resolution parameters:

2048	Number of spectrum channels	18.0	Energy resolution (FWHM) at 122 keV, keV
1.0	Channel-to-energy conversion factor, keV/channel	90.0	Energy resolution (FWHM) at 1332 keV, keV

Background gamma-ray peak and continuum intensities, cps:

0.013	Count rate in 185.7 keV peak of U-235	0.0003	Count rate in 661.6 keV peak of Cs-137
0.012	Count rate in 238.6 keV peak of Pb-212 (Th-232)	0.00015	Count rate in 1332.5 keV peak of Co-60
0.035	Count rate in annihilation 511.0 keV peak	0.02	Count rate in 1460.8 keV peak of K-40
0.006	Count rate in 609.3 keV peak of Bi-214 (U-238)	3	Continuum count rate (0 - 3 MeV)

Measurement setup   Calculation results   Options

Gamma Spectrum Generator Settings:

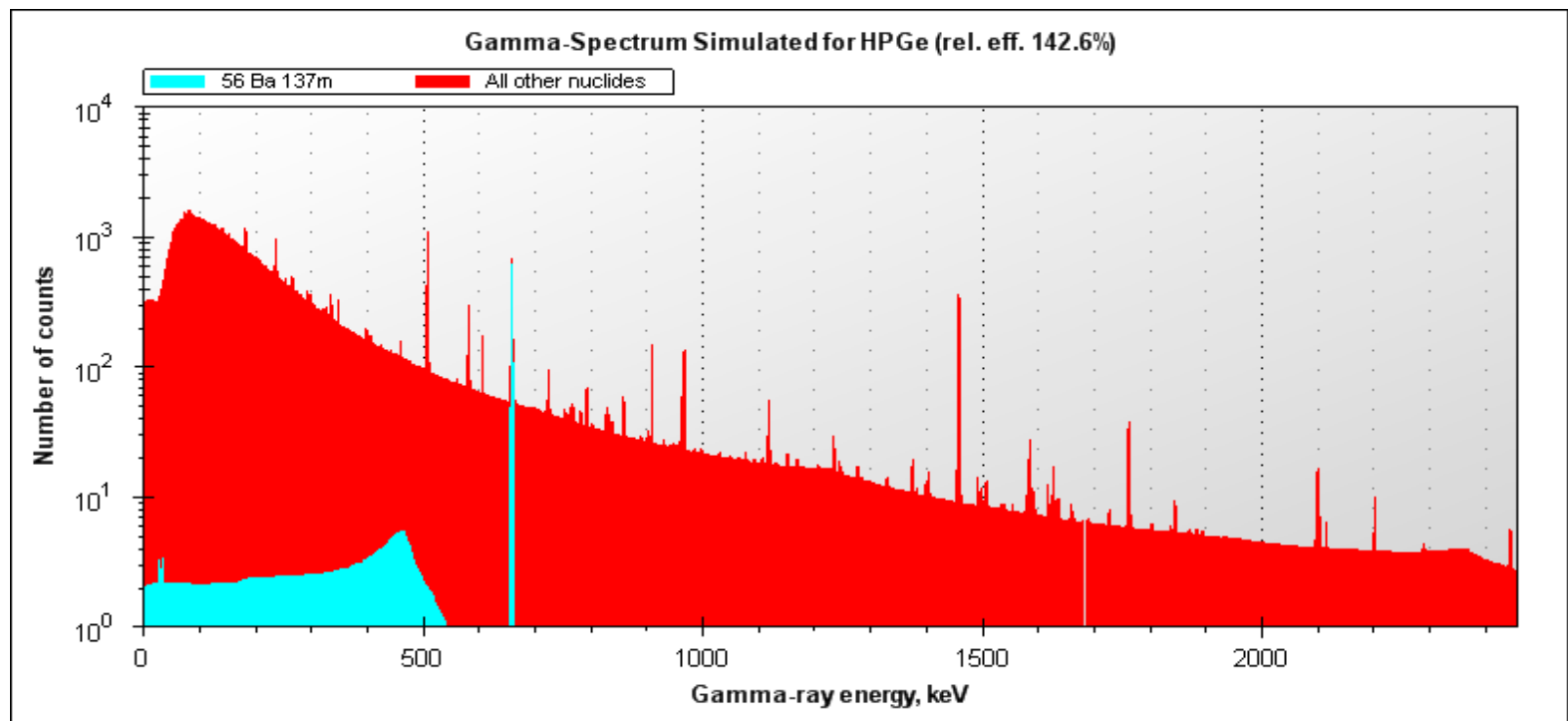
- ☐ Display detector efficiency curves
- ☐ Consider decay transformations during cooling and counting time intervals
- ☐ Consider effects of backscatter radiation
- ☐ Consider bremsstrahlung photon creation
- ☒ Simulate natural gamma-ray background

A respective option has to be selected on „Options“ tab to enable the background simulation

## GSG-PRO: Additional modeling features

Example: low-activity / low-background measurements

Inclusion of the background gammas results in a more realistic spectrum shape and MDA values, especially in low-activity measurements



- A spectrum simulated for a 10 Bq  $^{137}\text{Cs}$  source at the 10 mm distance from a 150% HPGe detector with natural background contribution included

October-2012

# Summary

- Gamma spectrum generator is a powerful tool for spectrum simulation
- Simulating spectra of arbitrary nuclides or nuclide mixtures
- Default and user-defined detector configurations (NaI, HPGe)
- Implemented in Nucleonica: point sources
- Educational and research tool

# Exercises

1. Use the GSG to simulate the spectrum of a 3 kBq  $^{60}\text{Co}$  source, taken for 1000 seconds at 25 cm from a 3"x3" NaI detector (default). Examine spectrum graph.
2. The same for a HPGe detector: coaxial, p-type, 50% rel. efficiency (default). Examine spectrum graph.
3. Simulate spectrum of  $^{137}\text{Cs}$ , for the same HPGe configuration.
4. Optional: Simulate spectrum of a mixture, e.g., natural Uranium or  $^{134}\text{Cs} + ^{137}\text{Cs}$ .